Abstract

Due to the stochastic nature of wind, the output power of wind turbines fluctuates. These power fluctuations can affect the power quality and cause voltage and frequency variations, especially in islanded grids. This paper deals with the application of a Flywheel Energy Storage System (FESS) for smoothing the power injected to the grid by a wind turbine driving a Doubly-Fed Induction Generator (DFIG). The FESS modeling as well as its proposed control scheme are discussed in detail. The FESS active power reference is obtained from a temporal moving average signal of the power of the wind turbine. The algorithm designed to calculate this set point takes into account the available energy of the flywheel at all times, as well as forecasts of future power demand. The result of the modeling of the whole system and the implementation of the flywheel control strategy are shown by simulation.

System description

In order to present the operation of FESS and the wind turbine, a system such as that shown in Fig. 1 has been modeled in DILSILENT PowerFactory software. This system consists of a wind turbine driving a DFIG and a FESS. The connection of the whole system with the external grid is via a coupling transformer.

As shown, the stator of the generator is directly connected to the network, while its rotor is connected to the network through a set of back-to-back power converters. The control system of the DFIG is based on [1]. FESS is modeled by a disk mechanically coupled to a Permanent Magnet Synchronous Machine (PMSM), which is connected to the grid through a set of back-to-back power converters and a two-winding transformer. The inertia time constant, \( H \), of the motor/generator and the rotating disk is \( H = 10s \). The rated speed of the system is \( 3000 \text{ rpm} \), while the minimum rotating speed is limited to \( 2250 \text{ rpm} \) and the maximum is \( 3750 \text{ rpm} \).

Control system of FESS

The control system of the FESS is presented in Fig. 2. As shown, the grid side converter controller is responsible for regulating the DC bus voltage of the system and control of the injected or absorbed reactive power to or from the external grid. The machine side converter controller is responsible for regulating the injected or absorbed active power to or from the external grid. The control algorithm implemented is based on the current vector control algorithm of the PM machine [2, 3].

The controller receives a power reference \( P_{*w} \) which is calculated by means of the block Reference power computer algorithm. \( P_{*w} \) is computed by means of reading the active power of wind generator \( P_{gen} \), and the rotation speed of the flywheel \( \omega \). A temporal moving average signal of the power of the wind turbine, \( P_{\text{mean}} \), is computed taking into account the \( L \) latest samples of \( P_{gen} \). The available energy \( E \) of the flywheel is calculated. Also the slope of \( P_{*w} \) is also computed as an indicator of forecasts of future power demand. If the available energy of FESS is becoming lower and forecasts of future power demand involve achieving faster the speed limits of the flywheel, \( L \) \( \rightarrow \) \( P_{\text{mean}} \) gets closer to \( P_{gen} \) \( \rightarrow \) \( P_{*w} \) \( \rightarrow \). More time is needed to reach the speed limits of the flywheel.

Simulation results

In the simulation results it can be seen that the total active power delivered to the external grid is far more constant than in the case without FESS. However, due to the strong variations of the power generated by the wind turbine, there have been situations in which it has been necessary to adjust the FESS active power setpoint in order to provide more time to reach the speed limits of the flywheel and hence make it available for more time during its operation. This change of the flywheel active power reference is obtained from an algorithm that changes a temporal moving average signal of the power of the wind turbine. This algorithm takes into account the available energy of the flywheel at all times, as well as forecasts of future power demand.

Conclusions

References